PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :		(11) International Publication Number: WO 00/25469
H04L 1/18	A1	(43) International Publication Date: 4 May 2000 (04.05.00)

(21) International Application Number: PCT/SE99/01910

(22) International Filing Date: 22 October 1999 (22.10.99)

(30) Priority Data:
60/105,372   23 October 1998 (23.10.98)   US

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S–126 25 Stockholm (SE).

(72) Inventors: NYSTRÖM, Johan; Kronobergsgatan 22, S–112 33 Stockholm (SE). FURUSKÄR, Anders; Vanadisvägen 8, S–113 46 Stockholm (SE). JÄVERBRING, Stefan; Glimmerstavägen 15, S–125 71 Älvsjö (SE). KHAN, Farooq; 810 Solook Drive, Parlin, NJ 08859 (US).

(74) Agent: ERICSSON RADIO SYSTEMS AB; Ericsson Research/Patent Support, S–164 80 Stockholm (SE).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: COMBINED HYBRID AUTOMATIC RETRANSMISSION REQUEST SCHEME

(57) Abstract

A transmitter operates using a scheme that allows receivers using either Type I Hybrid ARQ or receivers using Type II Hybrid ARQ to successfully receive and decode blocks from a common transmitter without the need for the transmitter be informed of which scheme is being employed by the receivers.

-1-

COMBINED HYBRID AUTOMATIC RETRANSMISSION REQUEST SCHEME

This application claims the benefit of U.S. Provisional Application No. 60/105,372, filed on October 23, 1998, the contents of which are hereby

5   incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention generally related to error handling in the field of communication systems and, more particularly to error handling using forward error correction (FEC), automatic retransmission requests (ARQ) and variable

10 redundancy in digital communication systems.

Reference is made to a related application, "Method and System for Measurement Based Automatic Retransmission Request in a Radiocommunication System" which was filed as U.S. Patent Application No. 09/168,064 on October 8, 1998, the contents of which are hereby incorporated by reference in its entirety.

15 The growth of commercial communication systems and, in particular, the explosive growth of cellular radiotelephone systems, have compelled system designers to search for ways to increase system capacity without reducing communication quality beyond consumer tolerance thresholds. One technique to achieve these objectives involved changing from analog modulation based systems

20 to digital modulation based systems.

In wireless digital communication systems, industry standards define most of the system parameters, including, for example, modulation type, burst format, communication and protocol. For example, the European Telecommunication Standard Institute (ETSI) established the Global System for Mobile

25 Communications (GSM) standard that uses time division multiple access (TDMA) to transmit control, voice and data information over radio frequency (RF) physical

channels or links and a Gaussian Minimum Shift Keying (GMSK) modulation scheme at a symbol rate of 271 kilosymbols per second (ksps). In the United States, the Telecommunication Industry Association (TIA) has published a number of Interim Standards, such as IS-54 and IS-136, that define various versions of Digital Advanced Mobile Phone Service (D-AMPS), a TDMA system that uses a Differential Quadrature Phase Shift Keying (DQPSK) modulation scheme for communicating data over RF links.

TDMA systems subdivide the allocated frequency into one or more RF channels. Each of the RF channels is further divided into a number of time frames. Each time frame is then divided into a number of timeslots, (e.g., three timeslots), wherein each timeslot corresponds to a physical channel. Logical channels are then formed from one or several physical channels.. In these systems the mobile stations communicate with one or more base stations by transmitting and receiving bursts of digital information over uplink and downlink RF channels.

Digital communication systems employ various techniques to handle erroneously received information. One such technique is FEC. In general, FEC involves transmitting additional bits that are used at the receiving end to verify the accuracy of the transmission, and if necessary, correct any errors. FEC techniques involve convolutional or block coding of the data prior to modulation, wherein it is common to refer to convolutional codes by a code rates (e.g., ½ and 1/3), wherein a lower code rates involves a greater number of code bits. Therefore, a lower code rate typically provides greater error protection. However, it also results in a lower user bit rate.

The technique used to select a code rate is called Link Adaptation (LA). LA works in conjunction with FEC by monitoring the quality of the channel or link and adjusting the code rate accordingly. For example, if the quality of the link is low, the code rate will be lowered. Alternatively, if the quality of the link is high, the code rate may be raised in order to provide a higher user bit rate.

-3-

Another common technique for handling erroneously received information is known as ARQ. In general, ARQ involves analyzing a received block of data for errors at the receiver and requesting that the sender retransmit the block of data if errors are detected. When processed by a receiver (e.g., a receiver in a mobile radio telephone), each block can, after demodulation, be evaluated for errors using a block check sequence and well known cyclic redundancy check techniques. If there are errors, then a request is sent back to the transmitting entity (e.g., a base station in a radiocommunication system) denoting the block to be resent using predefined ARQ protocols.

As one skilled in the art will appreciate, FEC techniques (e.g., FEC techniques including LA) may be combined with ARQ techniques. Such combined techniques are commonly referred to as hybrid ARQ techniques. Hybrid ARQ techniques permit correction of some received errors using FEC coding at the receiver, while correction of other errors may require retransmission.

FIG. 1 illustrates an exemplary hybrid ARQ scheme, known as Type I Hybrid ARQ. Type I Hybrid ARQ is used in conjunction with General Packet Radio Service (GPRS), wherein four FEC Modulation and Coding Schemes (MCS), CS-1 through CS-4 are employed with coding rates of 1/2, 2/3, 3/4, and 1, respectively. After one of the four FEC MCS is selected (using LA) for a current Logical Link Control (LLC) frame 110, segmentation of this frame to Logical Link Control (LLC) blocks, corresponding to the selected coding scheme, is performed. The LLC blocks include a payload of information 111, a frame header (H1) and a frame check sequence (FCS). The LLC blocks are coded with the selected rate forming a coded block 112. In order to reduce the number of bits in the coded block, bits can be removed using a known puncturing pattern to form the punctured coded block that will be used as the radio link control (RLC) block 113. If an RLC block is found to be erroneous at the receiver (i.e., it has errors which cannot be corrected) and needs to be retransmitted, the originally selected

-4-

FEC coding (and puncturing) scheme is used for retransmission (i.e., this system employs fixed redundancy for retransmission purposes).

Another exemplary hybrid ARQ scheme, known as Incremental Redundancy (IR) or Type II hybrid ARQ, provides for additional redundant bits to be transmitted if the originally transmitted block cannot be decoded. This scheme is conceptually illustrated in FIG. 2. Therein, multiple decoding attempts are made by the receiver. First the receiver attempts to decode the originally received data block. If the receiver is unable to decode the originally received data block, the receiver sends a retransmission request to the sender. The receiver then receives additional redundant block R1, which it uses in conjunction with the originally transmitted data block to attempt decoding. The probability of decoding is increased due to the diversity of the two transmitted blocks. The Type II Hybrid ARQ retransmission (R1, R2) is optimized to be decoded in combination with previous transmissions and may or may not be separately decodable. If the receiver still cannot decode the data block, the receiver obtains another block of redundant information R2, which it uses in conjunction with the originally received data block and the block of redundant bits R1 to attempt decoding for a third time. This process can be repeated until successful decoding is achieved.

For a further discussion of Type II Hybrid ARQ, reference is made to "Complementary Punctured Convolutional (CPC) Codes and Their Applications," by S. Kallel in *IEEE Transactions on Communications*, volume 23, number 6, published June 1995, the content of which is hereby incorporated by reference in its entirety.

Presently, using the above techniques, if a receiver using Type I Hybrid ARQ attempts to communicate with a transmitter using Type II Hybrid ARQ, assuming the coding scheme of the first transmitted block was known to the receiver, the receiver would not be able to decode any retransmission. In addition, even if the coding scheme for the retransmission was communicated to the Type I Hybrid ARQ receiver, the quality of service would be greatly diminished since the

-5-

Type I Hybrid ARQ receiver will discard previous transmissions and the retransmissions are not optimized to be separately decodable.

Therefore, it is desirable for a transmitter to operate using a scheme that will allow receivers using either Type I Hybrid ARQ or receivers using Type II Hybrid ARQ to successfully receive and decode blocks from a common transmitter without the need for the transmitter to know which scheme is being employed by the receivers.

SUMMARY OF THE INVENTION

The present invention describes a transmitter that operates using a scheme that allows receivers using either Type I Hybrid ARQ or receivers using Type II Hybrid ARQ to successfully receive and decode blocks from a common transmitter without the need for the transmitter be informed of which scheme is being employed by the receivers.

According to a first aspect of the present invention, provided is a system for communicating blocks of information to and from a transmitter and a receiver. The system comprises a transmitter that operates in an ARQ transmission mode and a plurality of receivers including a first receiver that operates in a first reception mode and a second receiver that operates in a second reception mode. The first receiver and the second receiver communicate with the transmitter while the transmitter operates in the ARQ transmission mode.

According to a further aspect of the present invention, provided is a communication device that operates in an ARQ mode. The communication device comprises a memory that stores a plurality of coding schemes in a predetermined order. The communication device also includes a receiver that receives a block and one or more retransmitted blocks. The receiver individually processes each of the one or more retransmitted blocks using a different coding scheme corresponding to the predetermined order of the coding schemes stored in the memory. In addition, the block and each of the one or more retransmitted blocks

-6-

are coded using the plurality of coding schemes and have a substantially equal probability of being independently decoded by the communication device.

According to a further aspect of the present invention, provided is a method of transmitting and receiving blocks in a communication system. The method comprises transmitting the blocks in an ARQ transmission mode; receiving the blocks, at a first receiver, operating in a first reception mode; and receiving the blocks, at a second receiver, operating in a second reception mode.

According to a further aspect of the present invention, provided is a method of receiving a block from a transmitter. The method comprises storing a plurality of coding schemes in a predetermined order; receiving, at a receiver, the block and one or more retransmitted blocks from the transmitter; and individually processing, at the receiver, each of the one or more retransmitted blocks using a different coding scheme corresponding to the predetermined order of the plurality of coding schemes. Each block and each of the one or more retransmitted blocks are coded using the plurality of coding schemes and have a substantially equal probability of being independently decoded by the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will be understood by reading this description in conjunction with the drawings in which:

FIG. 1 illustrates an exemplary FEC scheme;

FIG. 2 illustrates an exemplary hybrid ARQ scheme;

FIG. 3 is a flow chart of a process performed by an exemplary transmitter of the present invention;

FIG. 4 illustrates an exemplary hybrid ARQ scheme according to the present invention;

FIGS. 5A & 5B are flow charts processes performed by exemplary receivers of the present invention;

-7-

FIGS. 6A & 6B illustrate the exemplary MCSs for EGPRS; and

FIGS. 7A & 7B illustrate exemplary coding and puncturing schemes of the present invention.

DETAILED DESCRIPTION

5   The present invention utilizes a new technique in which the transmitter does not need to be informed of the actual mode (e.g., Type I or Type II Hybrid ARQ) used by the receiver.

The following exemplary embodiments are provided in the context of TDMA radiocommunication systems. However, those skilled in the art will

10   appreciate that TDMA is merely used for the purposes of illustration and that the present invention is readily applicable to other types of access methodologies including frequency division multiple access (FDMA), code division multiple access (CDMA) and hybrids thereof.

Moreover, operation in accordance with the GSM system is described in

15   European Telecommunication Standard Institute (ETSI) documents ETS 300 573, ETS 300 574, and ETS 300 578, which are hereby incorporated by reference in their entireties. Therefore, the operations of the GSM system in conjunction with the present invention is only described herein to the extent necessary for understanding the present invention. Although, the present invention is described

20   in terms of exemplary embodiments in an enhanced GRPS system, those skilled in the art will appreciate that the present invention could be used in a wide variety of other digital communication systems, such as those based on wideband CDMA or wireless Asynchronous Transfer Mode (ATM).

FIG. 3 illustrates a technique for transmitting blocks to a receiver in

25   accordance with a first embodiment of the present invention, wherein blocks are transmitted and retransmitted to a receiver using different coding schemes. A coding rate from a coding scheme is selected in step 320 (e.g., $[1, 1/2, \ldots, 1/n]$, $[1, 2/3, \ldots, 2/n]$, or $[1, 3/4, \ldots, 3/n]$). For purposes of illustration, the first

-8-

code rate sequence (i.e., (1, 1/2, . . . 1/n)) is used with a selective repeat ARQ scheme in the following discussion. A coded block using a first coding scheme P_1 (e.g., a convolution and/or puncturing scheme) is transmitted to a receiver in step 322. In step 324, the transmitter awaits an acknowledgment signal (ACK). If no ACK is received or if a non-acknowledgment signal (NACK) is received, then the same block is transmitted in step 326 using a second coding scheme. If in step 328, no ACK is received or if a non-acknowledgment signal (NACK) is received, then the same block is transmitted in step 330 using a third coding scheme. This process can be repeated for n number of coding schemes P_n at which point the process returns to step 322 with coding scheme P_1.

The second (and subsequent) coding schemes are optimized to have substantially the same probability of decoding as the first coding scheme. Since, for example, a Type I Hybrid ARQ receiver will decode successive blocks separately and a Type II Hybrid ARQ receiver will decode successive blocks jointly, by using coding schemes that have diversity as well as have substantially the same probability of decoding, both Type I and Type II Hybrid ARQ receivers will be able to decode the transmitted blocks without significantly reducing the quality of service for the transmission.

In order to optimize the coding schemes to have substantially the same probability of decoding, the different codes need to have a high number of distances between corresponding trellis paths. Each trellis path, for example, corresponds to a polynomial of a convolutional code that is punctured using a particular puncturing pattern. In order to increase the probability of decoding a particular coding scheme, the minimum distance for all of the trellis paths should be as high as possible (e.g., for a code rate of 1/3 and a constraint length of 7, a high value for the minimum distance is 14-15) In addition, the actual occurrence of the minimum distance for all trellis paths should be kept as low as possible (e.g., 1). Once a coding scheme is selected (e.g., P_1) using the above method, then the next best coding scheme is selected and so forth (e.g., P_2, P_3, P_n). The

next best coding scheme is determined by using the same procedure as stated above with respect to the best coding scheme.

Once multiple coding schemes are determined which have substantially the same probability of decoding, the coding schemes can be optimized for joint decoding by selecting coding schemes that, in combination, have a high minimum distance. That is, for example, the differences in trellis paths using the first coding scheme can be examined in combination with the differences in trellis paths using additional coding schemes in order to measure the distance in trellis paths for all of the coding schemes.

An exemplary technique of generating three puncturing patterns (P_i, P_j, P_k) for use with the present invention is described below. A plurality of puncturing patterns P_i, where $i = 1$ to N are created that correspond to a desired code rate, (e.g., the puncturing patterns reduce the number of total output bits per convolutional code, thereby increasing the code rate). The minimum distance, d_{min_i} for each trellis path of P_i is calculated. A first threshold value, $d_{threshold\_1}$, is determined that represents an acceptable minimum distance threshold for a single puncturing pattern for a particular code rate of a communication system. A second threshold value, $d_{threshold\_2}$, is determined that represents an acceptable minimum distance threshold for the joint decoding of two puncturing patterns for a particular code rate of a communication system. A third threshold value, $d_{threshold\_3}$, is determined that represents an acceptable minimum distance threshold for the joint decoding of three puncturing patterns for a particular code rate of a communication system. Each successive threshold value will be less than or equal to the previous threshold value. The number of threshold values calculated corresponds to the number of puncturing patterns that will be used by the communication system of the present invention.

Three puncturing patterns (P_i, P_j, P_k) are selected such that: the minimum distance of P_i (d_{min_i}), the minimum distance of P_j (d_{min_j}), and the minimum distance of P_k (d_{min_k}) are all greater than $d_{threshold\_1}$; the minimum distance of P_i and

P_j (d_{min_i+j}), the minimum distance of P_j and P_k (d_{min_j+k}), and the minimum distance of P_i and P_k (d_{min_i+k}) are all greater than $d_{threshold\_2}$; and the minimum distance of P_i, P_j, and P_k (d_{min_i+j+k}) is greater than $d_{threshold\_3}$. Puncturing patterns which satisfy the above criteria are therefore optimized to be decodable both individually (e.g.,

5   in a Type I Hybrid ARQ system) and in combination (e.g., in a Type II Hybrid ARQ system).

FIG. 4 illustrates a schematic view of the exemplary technique illustrated in FIG. 3. The LLC frames 440 are segmented into blocks of different sizes depending on the MCS to be used. In an alternative embodiment of the present

10   invention, a fixed code rate is used and no coding or modulation adaptation is performed.

A FCS and a header (H1) are added to the each of the segmented blocks 441. The entire block is convolutionally encoded with a rate 1/n code to produce coded block 442. To achieve different code rates, some bits are then punctured

15   from the coded block 442. In an alternative embodiment of the present invention, the header (or a portion of the header) is less punctured, or not punctured at all, in order to increase the robustness of the header regardless of the MCS used. In addition, the header (or a portion of the header) can also be coded separately from the data using, for example, another convolutional code (possibly punctured) or a

20   block code. Furthermore, the header can have its own FCS in order to avoid false detection of the header. Successful decoding of the header with high certainty, allows for the reliable combining and decoding of blocks. This technique can be useful with Type II Hybrid ARQ receivers by making it easier for the receiver to determine the identity of the received block (since the identity is contained in the

25   header) so that it can be combined with the retransmitted block in the event that only the header could be decoded.

For each MCS, a number of puncturing patterns exist (e.g., $P_1 \ldots P_n$). If the initial code rate is less than 1, $P_1 \ldots P_n$ are not disjunctive. In addition, if the initial code is 1/n, $P_1 \ldots P_n$ are equal (e.g., no bits are punctured) and the IR

-11-

operation of Type II Hybrid ARQ reduces to that of a repetition code. In both Type I and Type II Hybrid ARQ mode, the first block, punctured with P_1, is transmitted to the receiver. If decoding is unsuccessful, the second block, punctured with P_2 is sent, and so forth. The difference between the Type I and Type II Hybrid ARQ operation, is that in the Type I mode, the block using P_1 is discarded if decoding fails, and the next attempt is based solely on the block using P_2.

In the Type II Hybrid ARQ mode, soft information about the block using P_1 is stored and joint decoding, e.g., by soft combining information from P_1 and P_2, is performed. Thus, the transmitter does not need to know whether the receiver is in a Type I or Type II Hybrid ARQ mode, since the receiver will either treat each block separately (e.g., in Type I mode) or joint decode the successive blocks (e.g., in IR mode).

FIG. 5A illustrates a technique for receiving and decoding blocks using a receiver operating in a Type I Hybrid ARQ mode according to the present invention. The first block is received in step 540. In step 542, the receiver determines if it was able to decode the block. If the receiver was able to decode the block, using a first coding scheme, an ACK is sent in step 544 and the receiver waits for the next block of an LLC frame (or a block from a new LLC frame). If the receiver is unable to decode the block, a NACK is sent in step 546 and the first block is discarded. A second block is received in step 548 and in step 550 if the transmitter can decode the block using a second coding scheme, then an ACK is sent in step 544. If the receiver is unable to decode the block, a NACK is sent to the transmitter and the second block is discarded in step 552. A third block is received in step 554 and in step 556 if the transmitter can decode the block using a third coding scheme, then an ACK is sent in step 544. If the receiver is unable to decode the block, a NACK is sent to the transmitter and the third block is discarded in step 558. This process can be repeated for *n* number of coding schemes at which point the process returns to step 540 using the first coding

-12-

scheme. The coding schemes (and their relative order) can be stored in the transmitter or can be sent to the transmitter in a separate control signal using, for example, side band signaling.

FIG. 5B illustrates a technique for receiving and decoding blocks using a receiver operating in a Type II Hybrid ARQ mode according to the present invention. The first block coded using a first coding scheme is received in step 560. In step 562, the receiver determines if it was able to decode the block. If the receiver was able to decode the block, using a first coding scheme, an ACK is sent in step 564 and the receiver waits for the next block of an LLC frame (or a block from a new LLC frame). If the receiver is unable to decode the block, a NACK is sent in step 566. A second block coded using a second coding scheme is received in step 568 and in step 570 if the transmitter can decode the block by joint decoding the first and second blocks, then an ACK is sent in step 564. If the receiver is unable to joint decode the blocks, a NACK is sent to the transmitter in step 572. A third block coded using a third coding scheme is received in step 574 and in step 576 if the transmitter can decode the block by joint decoding the first, second, and third blocks, then an ACK is sent in step 544. If the receiver is unable to decode the block, a NACK is sent to the transmitter in step 578. This process can be repeated for n number of coding schemes at which point the process returns to step 560 using the first coding scheme. The coding schemes (and their relative order) can be stored in the transmitter or can be sent to the transmitter in a separate control signal using, for example, in-band or side-band signaling.

The present invention will now be described with reference to providing Link Quality Control (LQC) in Enhanced GPRS. The initial code rate can be selected based on link quality measurements performed by the transmitter and/or receiver. Type II Hybrid ARQ operation is enabled by puncturing a different set of bits for retransmissions. Different switching points for selecting the initial code rate can be used in the LA and IR modes. In standard GPRS, selective ARQ is used and acknowledgments (ACKs) and non-acknowledgments (NACKs) are

-13-

signaled using bitmaps. In order to protect the header, the header is interleaved over four GSM bursts. Using the 8PSK uncoded mode, the present invention allows for the transmission of two RLC blocks per 20 milliseconds (ms). This allows better performance if using frequency hopping techniques while limiting the ACK/NACK bitmap size and allowing robust header coding.

Exemplary MCSs for EGPRS are illustrated in FIGS. 6A and 6B. The MSCs are divided into different families (e.g., A, B and C). Each family has a different basic unit of payload (e.g., 37, 28 and 22 octets, respectively). Different code rates within a family are achieved by transmitting a different number of payload units within a 20 ms block. For example, for families A and B, one, two, or four payload units are transmitted. For family C, only one or two units are transmitted.

In cases where four payload units are transmitted (MCS-7 and MCS-8), the payload units are split into two RLC blocks using separate sequence numbers and CRCs. The MCS-8 blocks are interleaved over only two bursts because it yields a better performance than interleaving over four bursts for high code rates, especially when the burst quality is uncorrelated when, for example, using a frequency hopping technique.

For an initial transmission, any MCS can be selected based on the current link quality. For retransmissions in the LA mode that require increased robustness, two alternative embodiments exist. In the first alternative embodiment, if MCS-7 or MCS-8 was initially used, the block can be retransmitted at half the original code rate using one MCS-5 or MCS-6 block respectively. In the second alternative embodiment, if MCS-4. MCS-5, or MCS- 6 was initially used, the block can be transmitted using two MCS-1, MCS-2, or MSC-3 blocks respectively. In the second alternative embodiment, two bits in the header will indicate that the RLC block has been split and the relative order of the parts of the RLC block. For example, a block that was initially transmitted using uncoded 8PSK can be retransmitted using GMSK based MCS-3.

-14-

FIGS. 7A and 7B illustrate exemplary coding and puncturing schemes of the present invention using MCS-5 and MCS-8, respectively. The data block includes a Uplink State Flag (USF), a RLC Header, a Tail Bits (TB) field, a Final Block Indicator (FBI) field, an Extension bit (E) field, a data payload field, and a
5 Block Check Sequence (BCS).

In an exemplary embodiment of the present invention, each 8PSK block includes 1392 bits and each GMSK block includes 464 bits. The USF is 36 bits for 8PSK and 12 bits for GMSK. There are four stealing bits (SB) for 8PSK indicating two different header types and eight stealing bits for GMSK indicating
10 only one header type. The RLC headers are coded as discussed above and there are two bits used for the FBI and E fields. A 12 bit CRC and 6 bit tail are added to the payload for data protection.

In the description above, the blocks are derived with the same convolutional code, but with different puncturing patterns. Of course, one skilled
15 in the art will recognize that the blocks can be obtained by using different convolutional codes or block codes, or a combination of both. For example, the blocks can be obtained with different, relatively low-complex convolutional codes and turbo decoding can be applied in the receiver.

Although the invention has been described in detail with reference only to a
20 few exemplary embodiments, those skilled in the art will appreciate that various modifications can be made without departing from the invention. For example, the code rate before puncturing is not limited to any particular rate, but can be any value which is suitable for the use and environment of the present invention. Furthermore, a coded block does not have to be of a fixed size (i.e., a block may
25 vary in size from block to block). In addition, the coded block size could be, for example, a function of the initial code rate selected. Alternatively, a different coded block size could be used, for example, for each successive block.

-15-

Claims:

1.   A communication system comprising:

a transmitter that operates in an ARQ transmission mode; and

a plurality of receivers including a first receiver that operates in a first reception mode and a second receiver that operates in a second reception mode;

wherein said first receiver and said second receiver communicate with said transmitter while said transmitter operates in said ARQ transmission mode.

2.   The communication system of claim 1, wherein said first reception mode is an ARQ mode without using incremental redundancy and said second reception mode is an ARQ mode using incremental redundancy.

3.   The communication system of claim 1, wherein said ARQ transmission mode uses incremental redundancy, wherein retransmitted blocks are coded differently than an original transmitted block, and wherein each retransmitted block has a substantially equal probability of being independently decoded.

4.   The communication system of claim 3, wherein said first reception mode is an ARQ mode without using incremental redundancy and said second reception mode is an ARQ mode using incremental redundancy.

5.   The communication system of claim 2, wherein said first reception mode is a Type I Hybrid ARQ mode and said second reception mode is a Type II Hybrid ARQ mode.

6.   The communication system of claim 1, wherein said ARQ transmission mode is a Type II Hybrid ARQ mode adapted to retransmit blocks that are coded differently than an originally transmitted block, and wherein each retransmitted block has a substantially equal probability of being independently decoded.

-16-

7.   The communication system of claim 3, wherein said blocks are coded differently by changing a puncturing pattern for each retransmitted block.

8.   The communication system of claim 3, wherein said blocks are coded differently by changing a convolutional code for each retransmitted block.

5   9.   The communication system of claim 6, wherein said blocks are coded differently by changing a puncturing pattern for each retransmitted block.

10.   The communication system of claim 6, wherein said blocks are coded differently by changing a convolutional code for each retransmitted block.

11.   The communication system of claim 1, wherein said ARQ transmission
10   mode includes link adaptation.

12.   The communication system of claim 9, wherein said ARQ transmission mode includes link adaptation.

13.   The communication system of claim 7, wherein a code rate is varied by changing said puncturing pattern.

15   14.   The communication system of claim 3, wherein said ARQ transmission mode includes link adaptation and wherein different code rates for link adaptation as well as different coded versions for incremental redundancy are created by puncturing the same convolutional code.

15.   A communication device that operates in an ARQ mode comprising:
20   a memory that stores a plurality of coding schemes in a predetermined order; and

a receiver that receives a block and one or more retransmitted blocks, wherein said receiver individually processes each of said one or more retransmitted blocks using a different coding scheme corresponding to the predetermined order of said coding schemes stored in said memory, and wherein said block and each of said one or more retransmitted blocks are coded using said plurality of coding schemes and have a substantially equal probability of being independently decoded by said communication device.

16. The communication device of claim 15, wherein said ARQ mode is a Type I Hybrid ARQ mode.

17. The communication device of claim 15, wherein each of said coding schemes uses a different puncturing pattern.

18. The communication device of claim 15, wherein each of said coding schemes uses a convolutional code.

19. A method of transmitting and receiving blocks in a communication system comprising:

transmitting said blocks in an ARQ transmission mode;

receiving said blocks, at a first receiver, operating in a first reception mode; and

receiving said blocks, at a second receiver, operating in a second reception mode.

20. The method of claim 19, wherein said first reception mode is an ARQ mode without using incremental redundancy and said second reception mode is an ARQ mode using incremental redundancy.

21. The method of claim 19, wherein said ARQ transmission mode uses incremental redundancy, wherein retransmitted blocks are coded differently than an original transmitted block, and wherein each retransmitted block has a substantially equal probability of being independently decoded.

5   22. The method of claim 21, wherein said first reception mode is an ARQ mode without using incremental redundancy and said second reception mode is an ARQ mode using incremental redundancy.

23. The method of claim 20, wherein said first reception mode is a Type I Hybrid ARQ mode and said second reception mode is a Type II Hybrid ARQ

10   mode.

24. The method of claim 19, wherein said ARQ transmission mode is a Type II Hybrid ARQ mode adapted to retransmit blocks that are coded differently than an originally transmitted block, and wherein each retransmitted block has a substantially equal probability of being independently decoded.

15   25. The method of claim 21, wherein said blocks are coded differently by changing a puncturing pattern for each retransmitted block.

26. The method of claim 22, wherein said blocks are coded differently by changing a convolutional code for each retransmitted block.

27. The method of claim 24, wherein said blocks are coded differently by
20   changing a puncturing pattern for each retransmitted block.

28. The method of claim 24, wherein said blocks are coded differently by changing a convolutional code for each retransmitted block.

-19-

29.   The method of claim 19, wherein said ARQ transmission mode includes link adaptation.

30.   The method of claim 27, wherein said ARQ transmission mode includes link adaptation.

5   31.   The method of claim 25, wherein a code rate is varied by changing said puncturing pattern.

32.   The method of claim 21, wherein said ARQ transmission mode includes link adaptation and wherein different code rates for link adaptation as well as different coded versions for incremental redundancy are created by puncturing the
10   same convolutional code.

33.   A method of receiving a block from a transmitter comprising:
        storing a plurality of coding schemes in a predetermined order;
        receiving, at a receiver, said block and one or more retransmitted blocks from said transmitter; and
15   individually processing, at the receiver, each of said one or more retransmitted blocks using a different coding scheme corresponding to the predetermined order of said plurality of coding schemes,
        wherein said block and each of said one or more retransmitted blocks are coded using said plurality of coding schemes and have a substantially equal
20   probability of being independently decoded by the receiver.

34.   The method of claim 33, wherein said ARQ mode is a Type I Hybrid ARQ mode.

-20-

35. The method of claim 33, wherein each of said coding schemes uses a different puncturing pattern.

36. The method of claim 33, wherein each of said coding schemes uses a convolutional code.
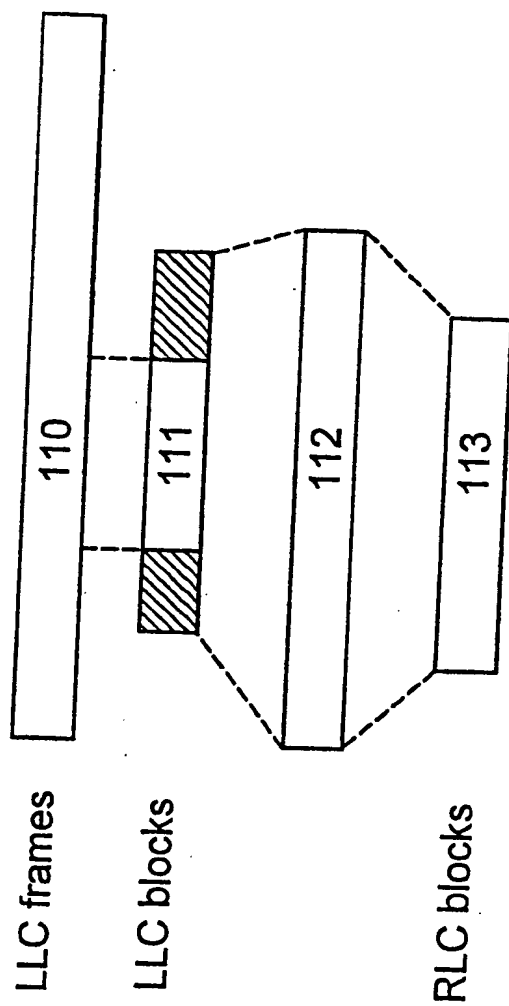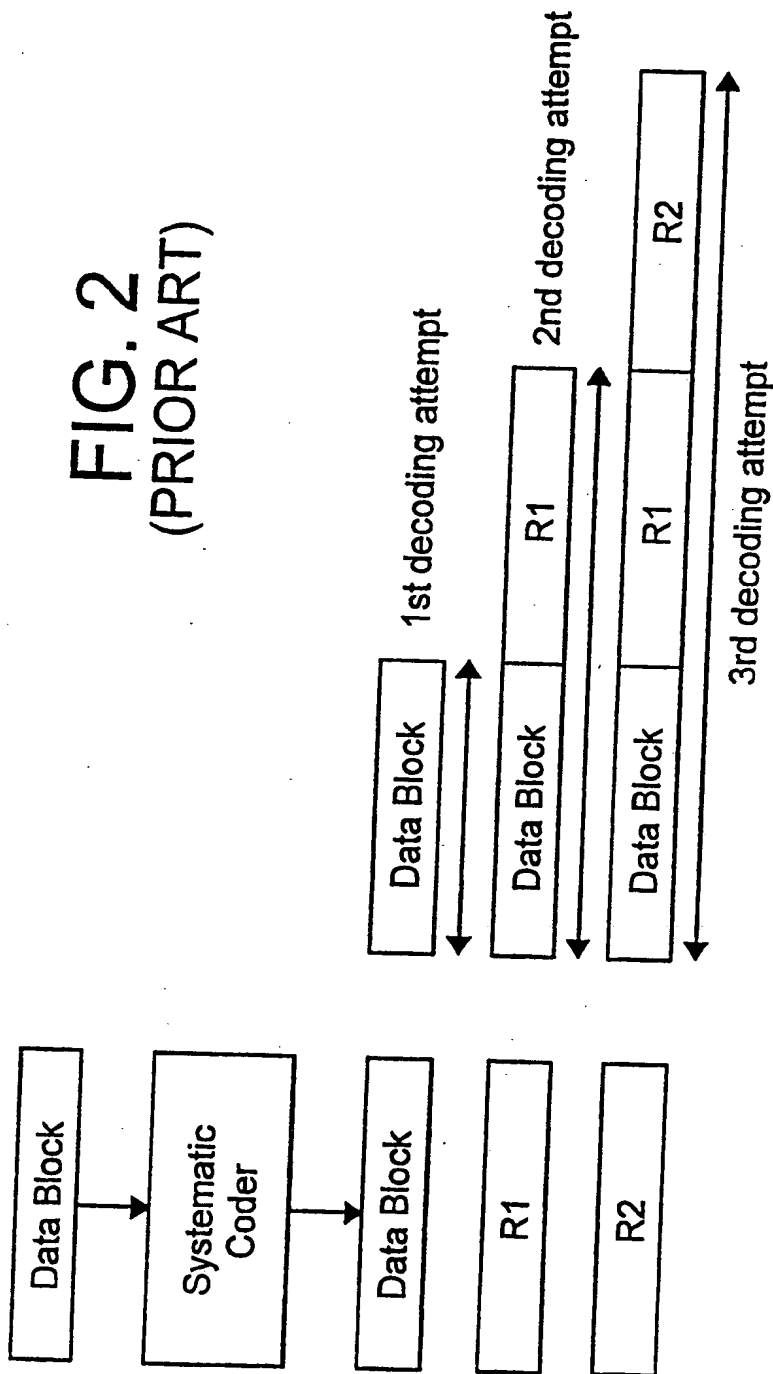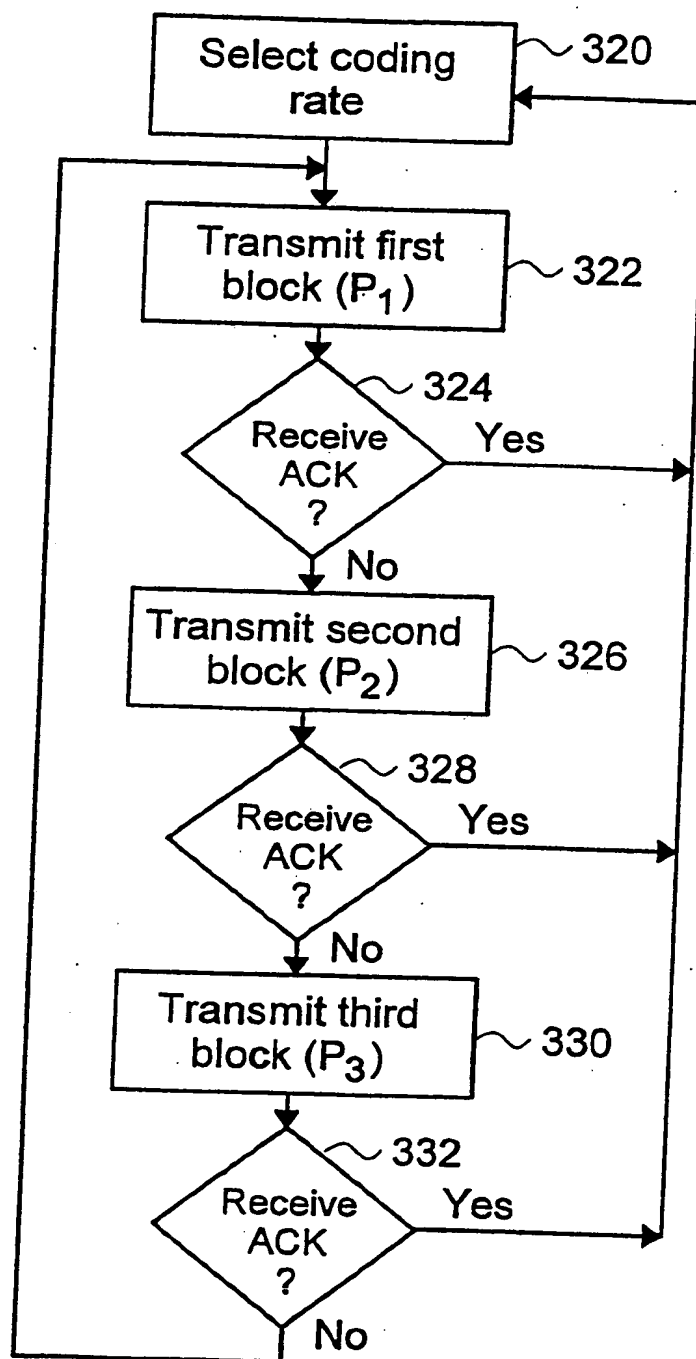
LLC frames 110

LLC blocks 111

112

RLC blocks 113

FIG. 1
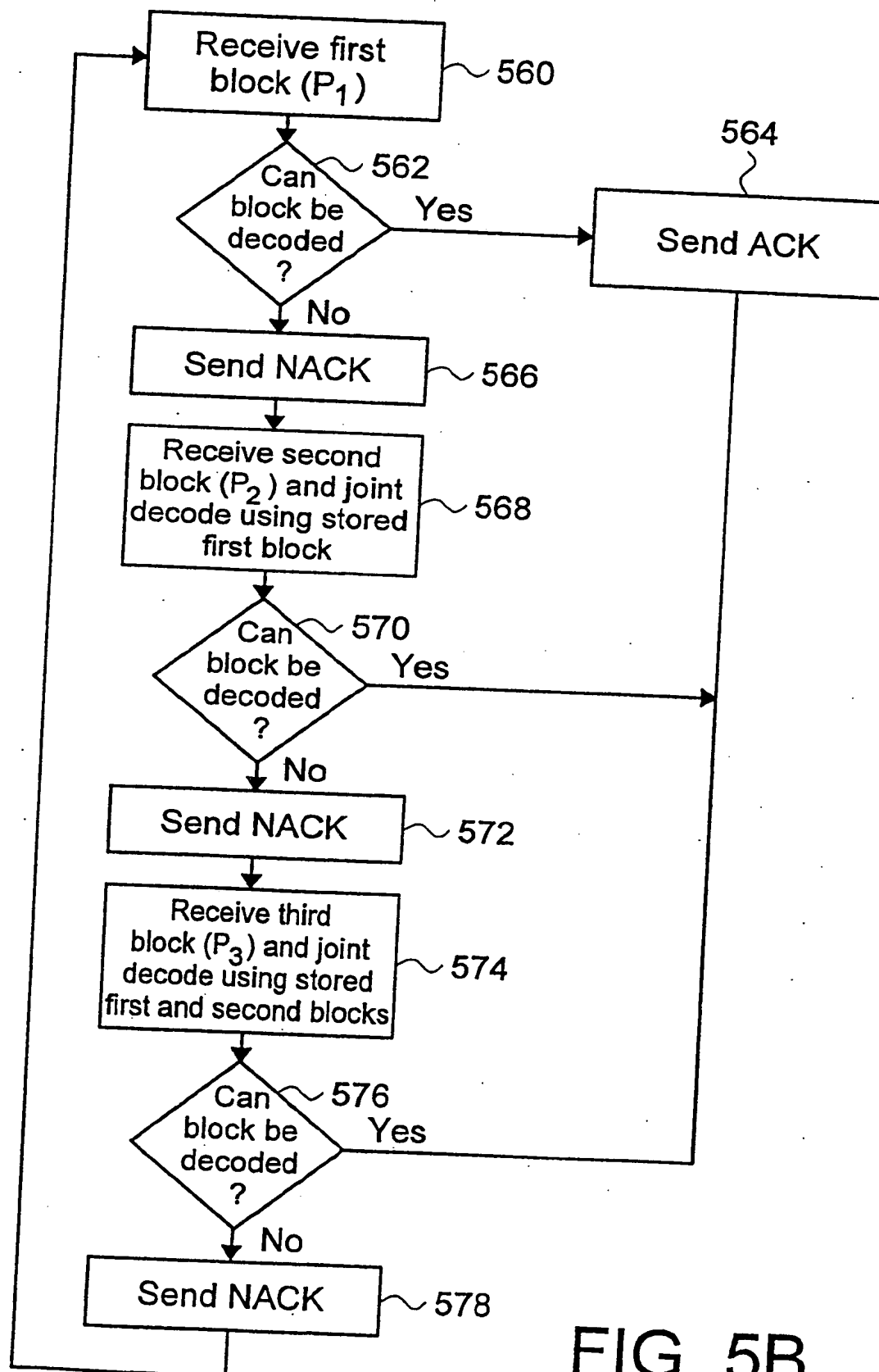## (PRIOR ART)

FIG. 2
(PRIOR ART)

FIG. 3

FIG. 4

FIG. 5A

Receive first block (P$_1$) — 560

Can block be decoded? — 562

Yes → Send ACK — 564

No

Send NACK — 566

Receive second block (P$_2$) and joint decode using stored first block — 568

Can block be decoded? — 570

Yes →

No

Send NACK — 572

Receive third block (P$_3$) and joint decode using stored first and second blocks — 574

Can block be decoded? — 576

Yes →

No

Send NACK — 578
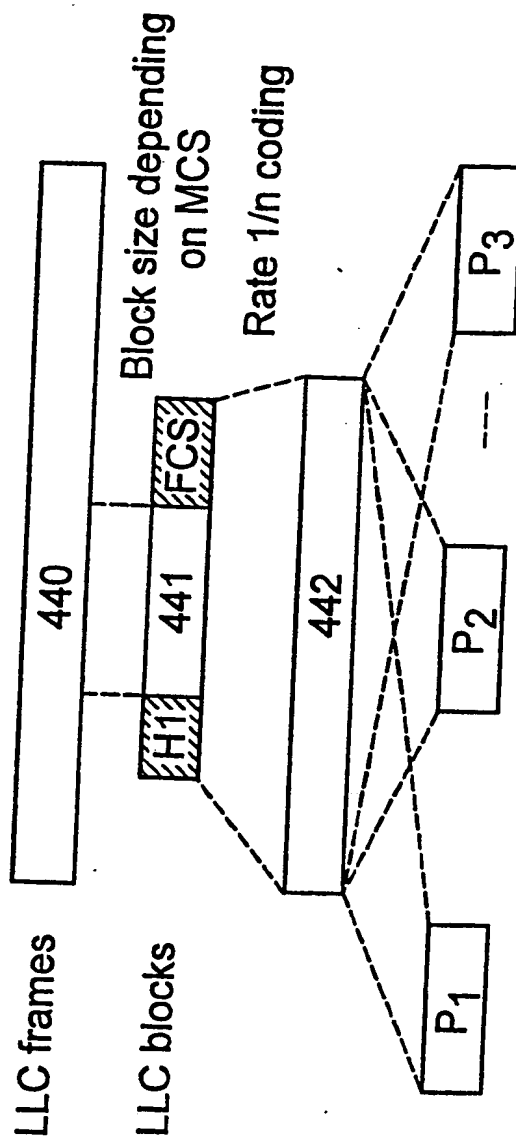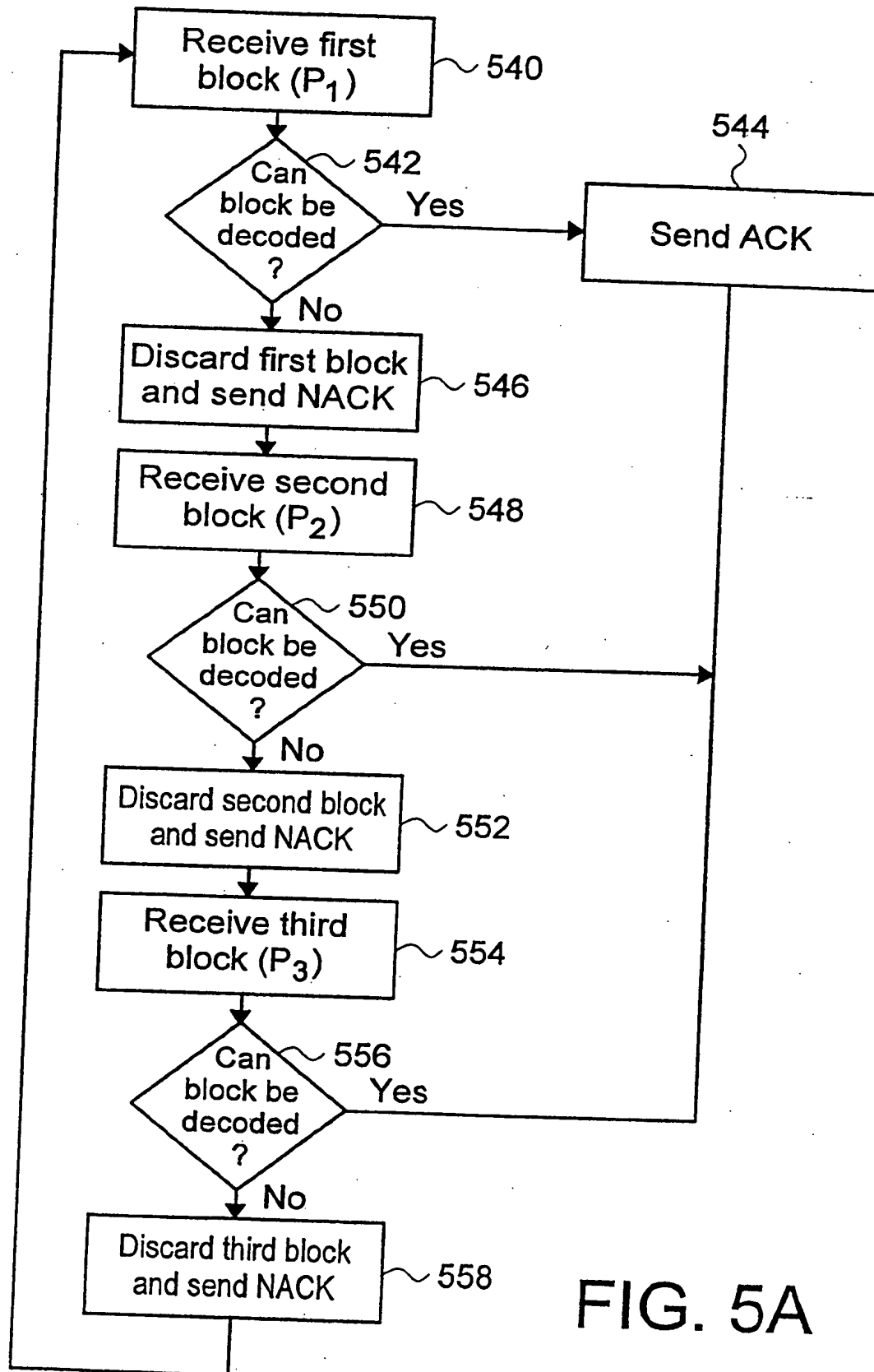
FIG. 5B

Scheme	Modulation	Maximum Rate [kbps]	Code Rate	Header Code Rate	Blocks per 20 ms	Family
MCS-8	8PSK	59.2	1.0	0.35	2	A
MCS-7		44.8	0.76	0.35	2	B
MCS-6		29.6	0.49	1/3	1	A
MCS-5		22.4	0.37	1/3	1	B
MCS-4	GMSK	17.6	1.0	1/2	1	C
MCS-3		14.8	0.80	1/2	1	A
MCS-2		11.2	0.66	1/2	1	B
MCS-1		8.8	0.53	1/2	1	C

FIG. 6A
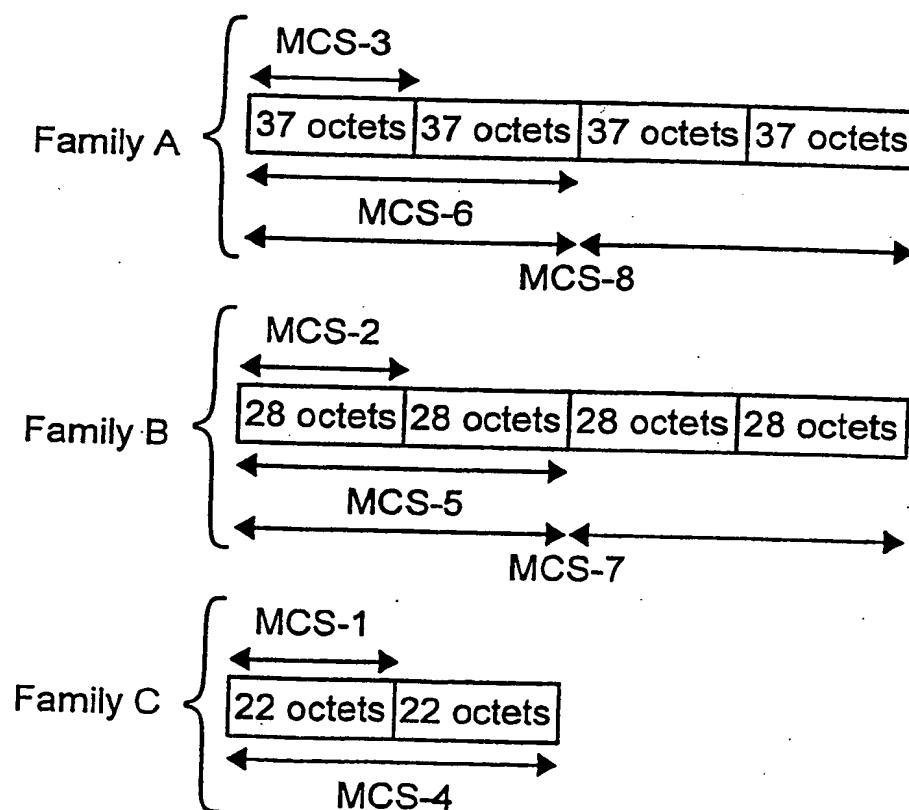
FIG. 6B

FIG. 7A
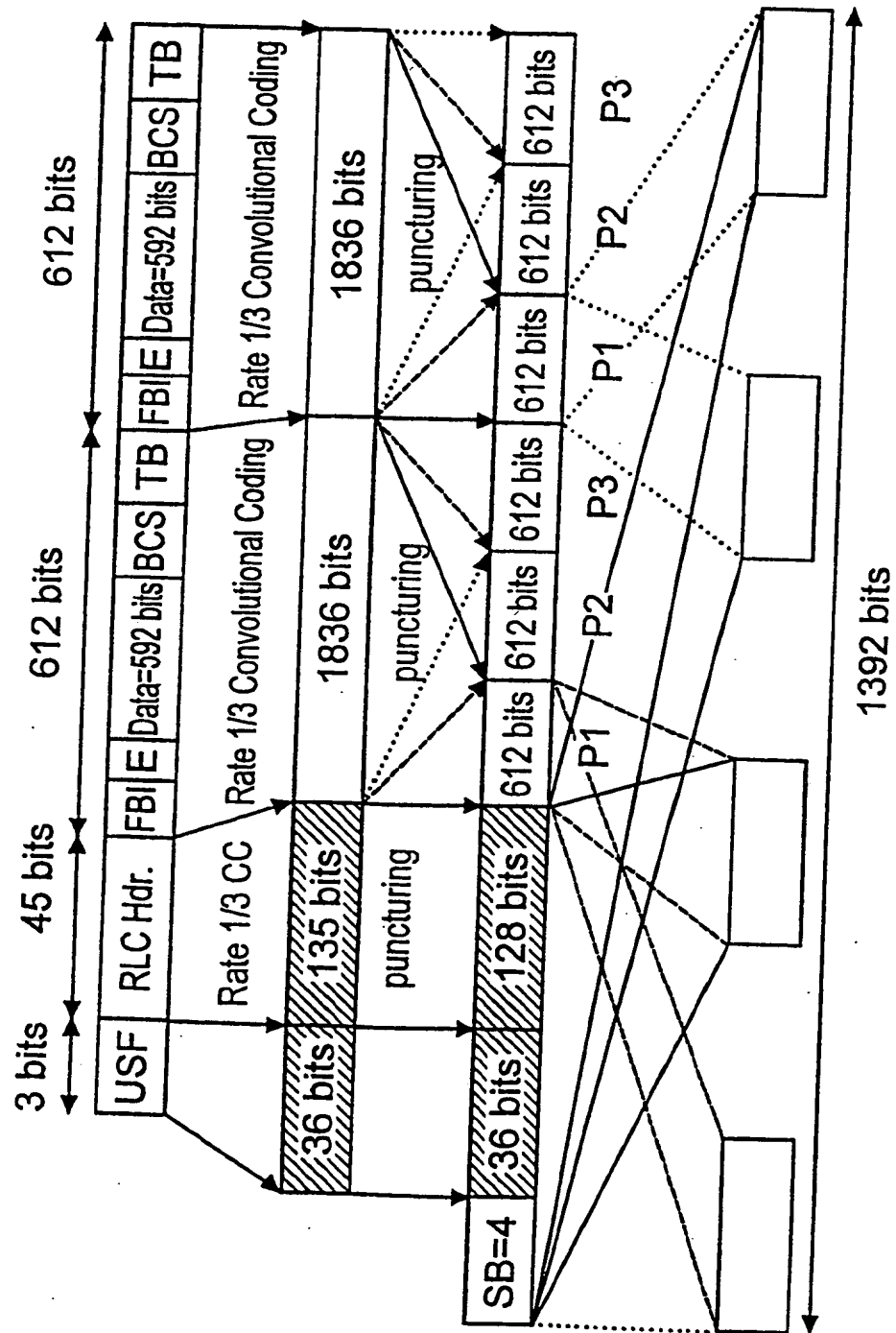
FIG. 7B
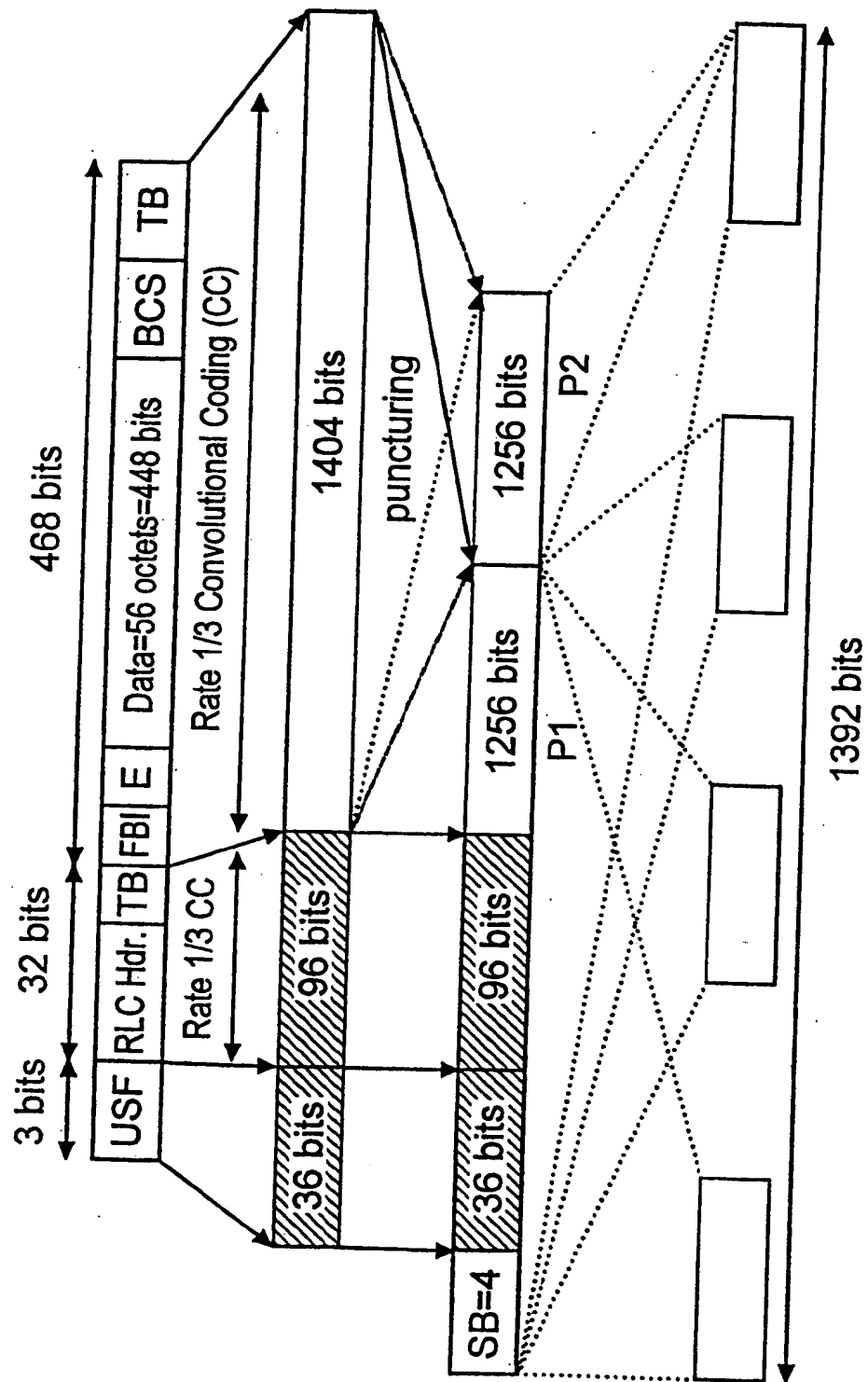
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04L 1/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Retransmission schemes for meteor-burst communications, Sandberg, S.D. et al, Computers and Communications, 1990. Comverence Proceedings., Ninth Annual International Phoenix Conference on, 1990, Page(s): 246-253, page 248,hs, line 9 – page 249,vs, line 15; abstract; paragraph II	1,3,6-19,21, 24-25,27-36
A	Performance of Reed-Solomon coded type-1 hybrid ARQ scheme on fading channels, Tanaka, H. et al, Global Telecommunications Conference, 1996, Globecom '96, Communications: The Key to Global Prosperity Volume:3, 1996, Page(s): 2148-2152 vol. 3, see paragraph 1,3.3	1-36

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 March 2000

Date of mailing of the international search report

2 7 -03- 2000

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Peder Gjervaldsaeter/cs
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document; with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5671156 A (VIJITHA WEERACKODY ET AL), 23 Sept 1997 (23.09.97), column 4, line 23 - column 6, line 37 --	1-36
A	IEEE Transactions on Communications, Volume 43, No 6, June 1995, Samir Kallel, "Complementary Punctured Convolutional (CPC) Codes and Their Applications", page 2005 - page 2009, abstract --	1-36
P,A	WO 9912303 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)), 11 March 1999 (11.03.99), page 5, line 22 - page 6, line 7, claim 1 --	1-36
P,A	Adaptive hybrid ARQ scheme using concetenated FEC for ATMover wireless links, Ji-Seob Sim et al, Electronic Letters Volume: 34 24, 26 Nov. 1998, Page(s): 2303-2304, see whole document -- ---------	1-36

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5671156 A	23/09/97	CA	2172567 A	01/10/96
		EP	0735774 A	02/10/96
		JP	8289295 A	01/11/96
		US	5581481 A	03/12/96
WO 9912303 A1	11/03/99	AU	9012198 A	22/03/99